Sky Surveys: Protostars to Protogalaxies
ASP Conference Series, Vol. 43, 1993
B. T. Soifer (ed.)

COSMIC EVOLUTION OF A SAMPLE OF INFRARED-LUMINOUS GALAXIES

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ABSTRACT A sample of faint, southern-hemisphere 60 μm sources ($f_{60} > 100$mJy) detected as part of the IRAS Additional Observations has been used, in conjunction with CCD imaging, to produce a list of faint infrared galaxies. Redshifts of this sample of galaxies can be compared with model predictions for several evolutionary scenarios; the comparisons show an excess of galaxies at higher redshifts ($z > 0.1$) compared with the predictions of models which assume no evolution of the infrared-galaxy luminosity function.

INTRODUCTION

The most luminous infrared galaxies detected by IRAS can be seen out to cosmologically interesting distances - i.e., distances such that the "look-back" time is a significant fraction of the age of the universe (e.g. Harwit et al 1987; Rowan-Robinson et al 1991). The ability to look back in time - admittedly at the limits of the IRAS surveys - allows us to examine whether the properties of these extremely luminous objects have evolved over time. As a first step, we can investigate whether the luminosity function of infrared luminous galaxies evolves over time.

Similar investigations have been carried out previously (e.g. Hacking et al 1987; Lonsdale and Hacking 1989; Saunders et al 1990; Lonsdale et al 1990). However, they have all been limited in one way or another - either by lack of depth in flux, incompleteness, or lack of spatial sampling This paper describes yet another attempt, in which a sample of adequate depth and spatial sampling is studied.

SAMPLE

Sources from 25 southern IRAS Additional Observation fields with the following characteristics were selected:

• Observed on at least 4 occasions by IRAS (implies completeness to at least 100 mJy).

• Above 40° galactic latitude

• No more than 10 100 μm sources (to guard against spurious "cirrus" sources)

CCD B and R images were taken of all sources (except for known bright galaxies) on the CTIO 0.9-m telescope. Galaxy positions were measured on the ESO and SRC sky survey films, using SAO stars as positional references, or on the CCD images, using reference stars whose positions were measured on the sky survey films relative to SAO stars.

The positional accuracy of the co-added AO grids was investigated using:

• Stars detected at 12 and 25 μm in these AO's and the corresponding northern AO's;

• Stars detected at 60 μm in the same data set (a very small number: 7 objects); and

• "Obvious" galaxy identifications (i.e. isolated bright objects) in the sample itself.

These investigations showed the positions to have a 1-σ error in the satellite in-scan direction of 6 arcsec and in the cross-scan direction of 22 arcsec. The positions also showed a small systematic offset (2 arcsec) in the in-scan direction.

In the larger samples, roughly 5% of the sources showed excessive (non-gaussian) positional errors.

REDSHIFTS

Redshifts for objects in most of the AO fields were taken from the literature or were measured using the RC spectrograph on the CTIO 4-m telescope. A few of the fields could not be finished, due to lack of time. Within the fields that were completely observed, we did not get redshifts for 100% of the IRAS sources, for one or more of the following reasons:

Inadequate signal to noise. This in practice occurred only when the candidate did not show emission lines, which in turn makes its identification as the IRAS source somewhat dubious (unless it was visually very bright). It is possible, but also not likely, that the absence of emission lines was due to a redshift high enough to shift Hα outside the coverage of the spectra ($z > 0.5$), leaving only relatively weak lines in the observable spectrum.

No suitable candidate. In some cases, all the objects in the field were very faint. This may be because the IRAS source is at high redshift, that is, an object with extreme far-ir/visible ratio, or it may reflect a bad source (e.g. cirrus contamination).

Missed candidate. In some cases only some candidates in the vicinity of the IRAS source were measured, usually because the revised positions on the CCD image moved new objects inside the 3-σ error ellipse, and in some of these cases none of the objects measured appeared to be the correct identification.

In cases where several candidate objects existed, the identification as the IRAS source was based on a mix of three criteria:

• Positional match (IRAS and optical positions).

• Visual brightness (visually brighter object is more probable identification).

• Appearance of spectrum (ir luminous galaxy more likely to have emission lines).

Fields with more than one or two "missing" sources were omitted from the analysis. Those with only one or two missing were included. It was felt that these could be safely included, as the unidentified sources were either (a) unbiassed with respect to redshift or (b) high-redshift, high-luminosity sources. Since the purpose of this study is to look for an excess of high-redshift sources, (and since such an excess is found), missing a few such sources will not prejudice the main goal of the study.

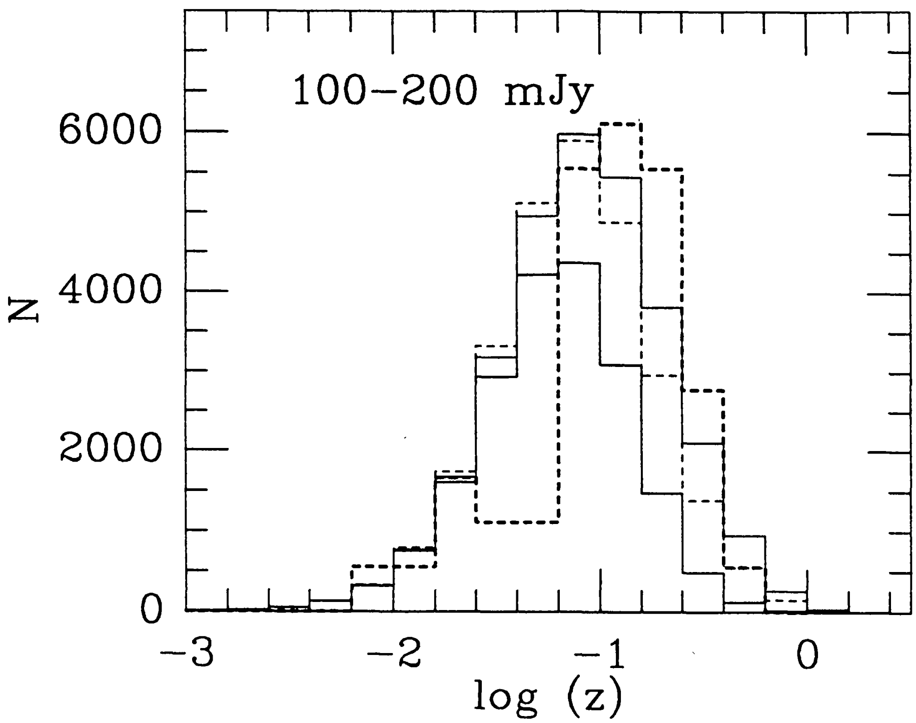

Figure 1: Plot of observed number vs. redshift distributions for sample galaxies with 60 μm flux densities between 100 and 200 mJy. The data are shown as a heavy dashed line. The predictions of three different models, derived from Hacking et al 1987, are also shown. The thin solid line is for a model without evolution, the dashed line is a simple density evolution model, while the dotted line is a luminosity evolution model.

A histogram of number vs. redshift is shown for each of two flux density intervals, compared with model predictions. The data are shown as heavy dashed lines. The a model with no evolution is shown as a solid line. A model with density evolution (proportional to $(1+z)^4$) as a dashed line, and a model with strong luminosity evolution (proportional to $(1+z)^3$) is shown as a dotted line.

The data show a clear deficit at moderate redshifts ($z = 0.01 - 0.1$) relative to the model predictions. This is likely to be due to a genuine deficiency of galaxies in that distance range, but the model normalization may be in error somewhat as well. A similar effect was also seen in the south galactic cap by Lonsdale et al (1990).

The data also show a clear excess over the predictions of the "no-evolution" model, and in fact suggest that even the weaker evolution models are insufficient to account for the excess. The situation would be accentuated if the model in fact requires re-normalization.

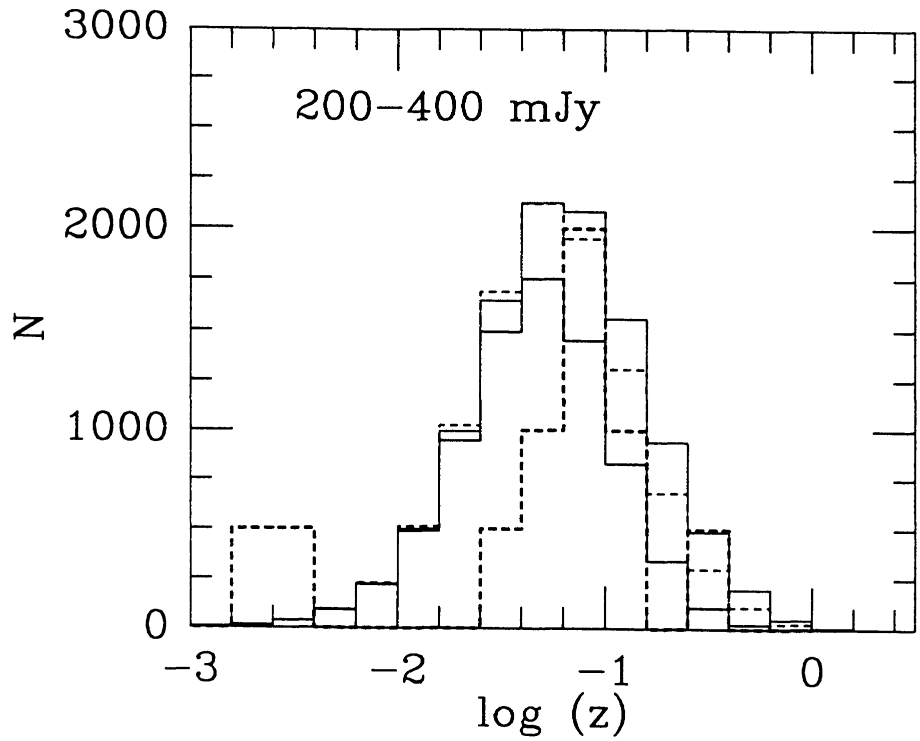

Figure 2: Data for observed number vs. redshift for galaxies between 200 and 400 mJy at 60 μm, plotted as in Fig. 1.

ACKNOWLEDGEMENTS

This program has been partially supported, both at Caltech and CTIO, by NASA under the ADP program.

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